CONTROL OF DWARF MISTLETOE IN A HEAVILY USED PONDEROSA PINE RECREATION FOREST:

Grand Canyon, Arizona

by
Paul C. Lightle and Frank G. Hawksworth
Principal Plant Pathologists

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USDA Forest Service
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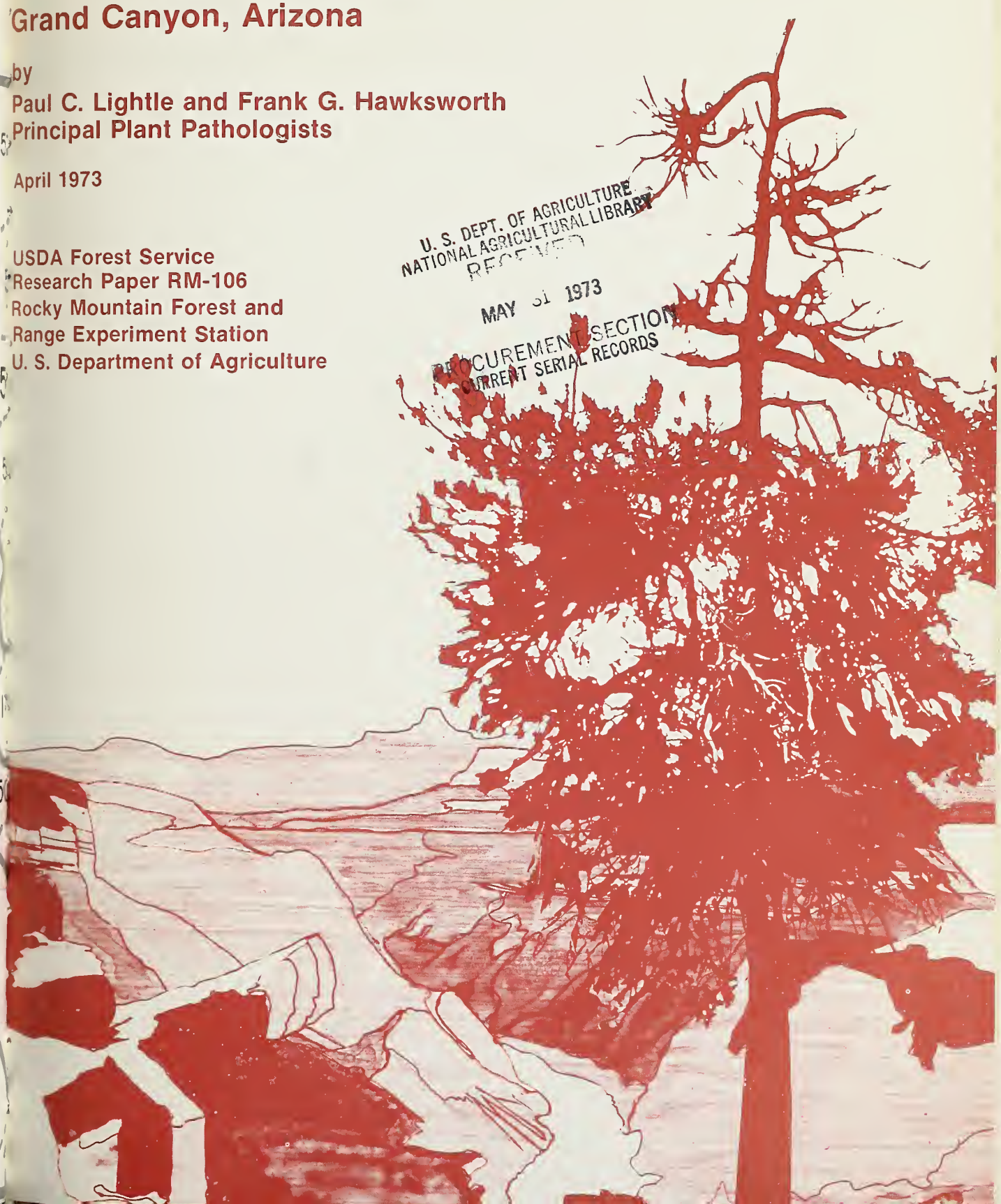
Rocky Mountain Forest and
Range Experiment Station
U. S. Department of Agriculture



Abstract

Southwestern dwarf mistletoe has been a problem in ponderosa pine on the South Rim of Grand Canyon for many decades. The National Park Service program to control the parasite, begun in 1949, was the first large-scale attempt to control dwarf mistletoe in a recreational forest. The area has been sanitized at about 5-year intervals since the initial treatment. This Paper describes the control effort, and compares the treated and untreated stands after 20 years. The original goal of the project—to reduce the level of dwarf mistletoe and protect the ponderosa pine forest—has been achieved. Recommendations for dwarf mistletoe control in recreational forests, based on knowledge gained from this project, are summarized.

Oxford: 443.3:412. **Keywords:** Dwarf mistletoe control, recreational forests, silvicultural control, *Arceuthobium vaginatum* subsp. *cryptopodum*, *Pinus ponderosa*.

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Rocky Mountain Forest and Range Experiment Station[1]

[1]*Central headquarters maintained in cooperation with Colorado State University at Fort Collins. Authors are stationed at Albuquerque, New Mexico and Fort Collins, respectively.*

FOREWORD

Dwarf mistletoe on the South Rim af Grand Canyan Natianal Park is considered a native pathagen in the panderasa pine farests af the area. The infectian intensity became a matter af deep cancern ta Park managers in the 1930's. Research in the late 1940's indicated a passible change in species campasitian in the panderasa pine type shauld the infectian cantinue at the same intensity. Park administratars decided in the 1950's ta adapt a caurse af resaurce management that wauld preserve the panderasa pine farest type, and wauld sustain the scenic and esthetic values alang the Park's Sauth Rim. Cantral practices have been cantinued since that time.

We nate with cansiderable satisfactian that the scenic values inherent in the South Rim ponderasa pine farest have been maintained alang the East Rim Drive. As the Park appraaches a new milestane in the praject, the maintenance phase af the pragram, this Research Paper is being published ta dacument the histary af jaint U. S. Natianal Park Service-Farest Service effart in the preservatian af the farest type and the esthetic values in a highly used recreatianal partian af a natural area. Ta the many farest research scientists, particularly the late Dr. Lake S. Gill, the present farest pathalagists af the Racky Mauntain Farest and Range Experiment Statian, Dr. Frank Hawkswarth and Dr. Paul Lightle, and the staff members and the Superintendents af Grand Canyan Natianal Park aver three decades, forest pathologists af future generatians will pay tribute far this dacumentatian.

William C. James
Park Planner
Office of Research and
Cansultative Services
Denver Service Center
Natianal Park Service

Eslie H. Lampi
Resaurce Management Specialist
Southwest Region
Natianal Park Service

ACKNOWLEDGMENTS

So many people have assisted in various phases of the project since its initial planning in 1947 that it is impossible to acknowledge them all. However, we would particularly like to thank foresters Robert Peterson, S. T. Carlson, W. G. James, Eslie Lampi, and Clyde Fauley of the National Park Service for their sustained interest and cooperation in the project. Dr. Lake S. Gill provided technical direction for the project from its inception until the mid 1950's, and followed it with interest even after his retirement in 1960. S. R. Andrews and T. E. Hinds of the Rocky Mountain Station also assisted in technical aspects of the work.

Contents

Control of Dwarf Mistletoe in a Heavily Used Ponderosa Pine Recreation Forest: Grand Canyon, Arizona

Paul C. Lightle and Frank G. Hawksworth

HISTORY OF THE CONTROL PROJECT

On the South Rim of the Grand Canyon, mortality of ponderosa pine (Pinus ponderosa Laws.) due to parasitism by southwestern dwarf mistletoe (Arceuthobium vaginatum ~~subsp.~~ cryptopodum (Engelm.) Hawks. & Wiens) has been recorded since before the turn of the century (MacDougal 1899). The National Park Service expressed concern about the dwarf mistletoe situation along the South Rim as early as 1933, and became increasingly concerned over the impact of the infestation in the ponderosa pine stands east of Grand Canyon Village. The severity of the infestation was noted by Gill (1940, 1946) and Mielke (1945). Many pole-sized and mature pines were dying, and the growth of trees in all size classes was seriously affected. A factor of even more consequence to the esthetics of the area, however, was that in some places, the ponderosa pine type was being replaced by Gambel oak (Quercus gambelii Nutt.).

In August 1947, Division of Forest Pathology[2] and National Park Service personnel met to review the situation on the ground. As a result of this meeting, the Division of Forest Pathology was requested to make a preliminary study to determine (1) the need for and feasibility of control, and (2) the general procedures to be followed if control was to be practiced. The survey was made in the fall of 1947, and the results were summarized in a report by Gill (1949).

Gill emphasized that the Park Service's long-range plans for the area—including whether ponderosa pine, near the Rim at least, was worth preserving for future generations—had to be decided before control could be considered. He pointed out that, left unchecked, the ponderosa pine stands would continue to deteriorate, but that a decision to control the parasite must include the commitment to at least one additional sanitation treatment.

As native parasites, dwarf mistletoes are generally in long-term equilibrium with their hosts. At Grand Canyon, however, dwarf mistletoe on ponderosa pine appears to be an exception, probably because the stands are marginal. Ponderosa pine dwarf mistletoe is known to reduce seed production in heavily infected trees (Korstian and Long 1922), and in many areas it appeared to Gill (1949) that ponderosa pine stands had been replaced by Gambel oak. Apparently as older trees on the South Rim were killed by mistletoe, oak took over the sites. The increase in oak on the South Rim is unusual because it is due not only to root suckering, but also to seedling establishment. Elsewhere in the ponderosa pine type, oak increases almost exclusively due to suckering.

After thorough consideration of Gill's report in the light of Service policy, Park Service personnel decided the dwarf mistletoe infestation was so serious that a control project was warranted to save the stands along the East Rim Drive.

Financing for the control project with Pest Control funds was obtained by the National Park Service. Initial control was begun in September 1949 (Hawksworth 1951) and continued until June 1952 (Hawksworth 1952). Since then the area has been sanitized three times at about 5-year intervals. Technical guidance has been provided by the Division of Forest Pathology and the U. S. Forest Service. As part of the project, 10 sample plots were established in the treated areas and in nearby untreated stands so that the effectiveness of control could be assessed.

This is the first large-scale attempt to control dwarf mistletoe in a recreational forest. Since the project is well known and has been visited by many foresters, biologists, and forest pathologists, a thorough documentation of the project is warranted. To present a more complete historical account, we have therefore included references to several unpublished reports.

[2] *The Division of Forest Pathology, U. S. Department of Agriculture, was transferred from the Bureau of Plant Industry, Soils and Agricultural Engineering to the Forest Service in 1954, and became the Division of Forest Disease Research.*

The purpose of this Paper is to describe and evaluate the control effort after 20 years. The report consists of three major parts: (1) The control project, (2) the permanent study plots, and (3) suggestions for control in recreation forests.

THE FOREST AND DWARF MISTLETOE

The topography of the plateau south of the Rim is fairly uniform, with slightly rolling hills. Elevations range from 7,300 to 7,600 feet. The draws are usually less than 200 feet lower than adjacent ridges. In the eastern part of the area (from about 2 miles west of Grandview Point) the forest is nearly pure ponderosa pine. In the western portions, however, ponderosa pine predominates in the bottom sites, with pinyon (Pinus edulis Engelm.) and juniper (Juniperus osteosperma (Torr.) Little) on the ridges. Gambel oak is a frequent associate of ponderosa pine throughout the South Rim area. Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco), white fir (Abies concolor (Gord. & Glend.) Lindl.), and aspen (Populus tremuloides Michx.) occur at or below the canyon rim, but are insignificant components of the forests on the plateau.

Dwarf mistletoe occurs on ponderosa pine from near Yaki Point for about 10 miles along the East Rim to near the east end of the ponderosa pine type (Hawksworth 1967, fig. 1). The ponderosa pine stands near Grand Canyon Village and the Park Headquarters are apparently free of the parasite.

THE CONTROL PROJECT

Control Strategy

At the outset of the project it was fully realized that ponderosa pine dwarf mistletoe was a native parasite, and that attempts would be made to control, not eradicate, it. No control was to be attempted in areas that were not to be developed for scenic and recreational purposes. The Grand Canyon control project was

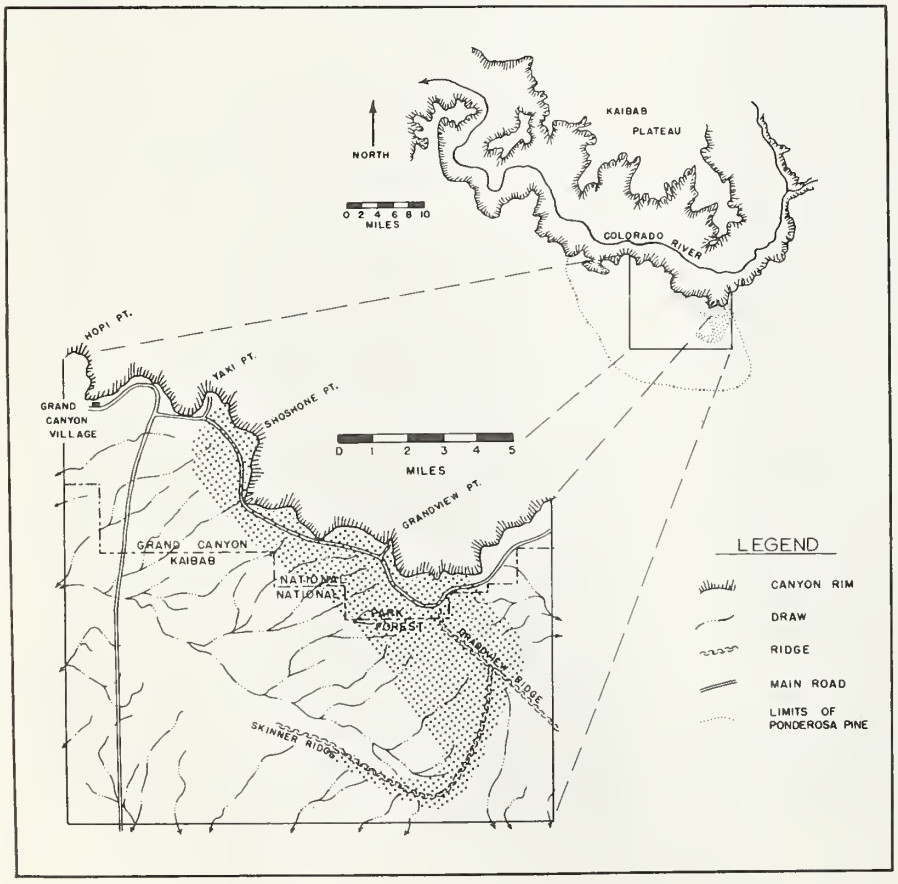


Figure 1.—
The South Rim of Grond Conyon showing the locotion of ponderoso pine stonds. The stippled oreo indicotes the stonds with dworf mistletoe infection (from Howksworth 1967).

undertaken to protect the ponderosa pine forest in the scenic and intensively used portions of the South Rim by reducing the levels of dwarf mistletoe. This was to be accomplished by removing mistletoe infections from trees to be protected, or otherwise isolating these trees from mistletoe infection (U.S. National Park Service 1949).

The plan was to apply control measures in sections 17 and 20 between the canyon rim and the East Rim Drive and Grandview Spur Road, a 300-foot strip along the south side of the East Rim Drive in sections 17 and 20, and a 300-foot roadside strip along both sides of this drive between Yaki Point Junction and the west boundary of section 17 (fig. 2). The 300-foot roadside strip was not continuous because of intervening pinyon-juniper areas (Hawksworth 1952). Dwarf mistletoe infected ponderosa pine was present on 680 acres (or 62 percent) of the 1,100 acres within the control area.

In 1956, Park personnel surveyed the area east of the original control area between the canyon rim and a proposed new road alinement, extending east to the end of the ponderosa pine type (James 1956). Because the survey showed that dwarf mistletoe was present throughout the area, an appraisal survey by the Albuquerque Forest Disease Laboratory, USDA Forest Service, was requested (Hawksworth 1956). Park personnel then decided to include this area in the control unit to (1) save the ponderosa pine type, (2) have a continuous roadside area pleasing to the visitor, and (3) have a consolidated control area that would be easier to maintain. Control measures were to be applied to infected ponderosa pines between the canyon rim and the East Rim Drive east of the originally treated area, to a 300-foot strip south of the Drive in the same area, and to infested areas further west along the realined road (fig. 2). (A 10-acre plot in section 21 was left untreated to compare with a 10-acre treated plot nearby in section 20.) Initial control work began in November 1956 and was completed in December 1957 (James 1958). This new area, designated as extension A, contained about 840 acres, most of which was uniformly and heavily infested with dwarf mistletoe.

In 1965 it appeared that dwarf mistletoe was reinvading the control area from the untreated stands to the south. A utility right-of-way about 30 feet wide had been clearcut near, and more or less parallel to, the south boundary of the control project. Park personnel decided to extend the control area to this clearcut strip to retard reinvasion of the treated area. Treatment of this area, called extension B, was begun in 1966 (fig. 2). About 408 acres of ponderosa pine type, most of which was heavily infested by dwarf mistletoe, were included in extension B.

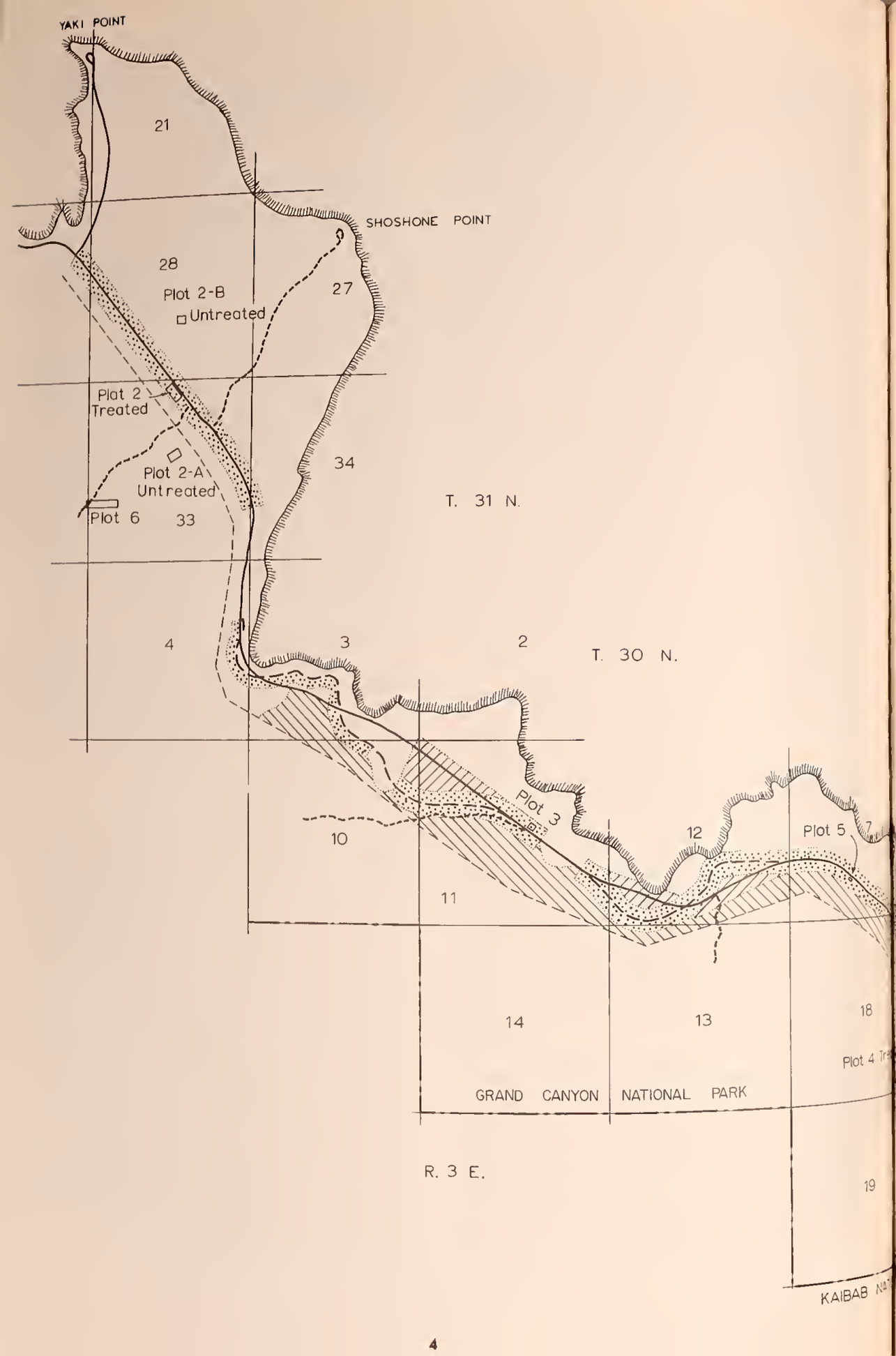
Control Methods

Feasibility of controlling ponderosa pine dwarf mistletoe by a systematic program of sanitation had already been demonstrated by studies at the Fort Valley Experimental Forest, near Flagstaff, Arizona (Gill and Hawksworth 1954). Sanitation consists of pruning lightly to moderately infected trees, and killing heavily infected ones.

Initial sanitation involved pruning, poisoning, or felling infected trees (Hawksworth 1951). For esthetic reasons, as many trees as possible were pruned. Trees were considered not prunable, and to be killed if:

1. Over half of the crown would be removed in pruning operations. This basic rule was not followed strictly, but was influenced by (a) the distribution of the mistletoe in the tree, (b) general tree health, (c) appearance of the tree after treatment, and (d) allowance for the later removal of additional infected branches that were not visibly infected at the time of the original treatment.
2. Mistletoe shoots were on or within 18 inches of the main stem. (In 1961 and subsequent years this was reduced to 12 inches.) Exceptions were: (a) some trees with infections on small branches, and (b) some trees with bole infections where the bole diameter was 12 inches or larger.

Gill (1949) emphasized that a satisfactory degree of control could not be achieved in one operation. Subsequent examination and sanitations were planned as an integral part of the project. The number of sanitations that would be required was not known at the beginning of the project, but inspections were to be made at 3- to 5-year intervals to determine the need for, and timing of, the next operation. A complicating factor in determining the extent of subsequent sanitation was that pruning was used very extensively in an attempt to save as many trees as possible (over half of the trees treated in the initial operation were pruned). It was realized at the outset that more sanitations would be needed for this type of operation than for control projects in timber-production forests, where infected trees are cut, and very few were pruned (for example, the mistletoe control operation on the Mescalero Apache Reservation, New Mexico — Hawksworth and Lusher 1956, Lightle and others 1967).



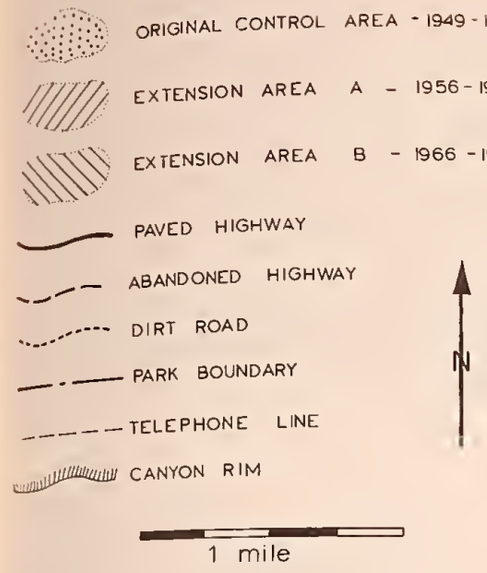


Figure 2.—
The Grand Canyon Dwarf Mistletae Cantral Praject, shawing the areas cavered in the initial aperatians and extensian areas A and B. The 10 permanent plats are alsa shawn.

Control Operations

The entire control area included about 2,348 acres:

Control Unit	Sanitation operations	
	Initial	Subsequent (Years)
Original area (1,100 acres)	1949-52	1954-55 1961-62, 1966-70
Extension A (840 acres)	1956-57	1961-62, 1966-70
Extension B (408 acres)	1966-69	none

In all operations, 68,400 tree treatments were recorded. It is not known how many individual trees were treated because some were pruned from two to four times, and some pruned trees developed so much mistletoe they had to be killed later. Although complete records are not available on the type of treatment for all years of the operation, apparently about one-third of the trees were pruned and two-thirds were killed by cutting or poisoning.

The initial sanitation treatments on the original control area relied much more heavily on pruning (53 percent of the trees treated) than did the first sanitations in extension area A (33 percent) or extension area B (20 percent). Factors involved in this change were the high cost of pruning trees and the frequent need for their re-treatment.

The three areas covered by the project—initial control, extension area A, extension area B—will be discussed separately. A chronology of the operations in the various control units is given in table 1.

Original Control Area

The 1,100 acres (see fig. 2) were initially sanitized in 1949-52. Additional sanitations were made in 1954-55 and 1961-62. Most of the area (except along the East Rim Drive west of section 4) was again sanitized in 1966-70. Thus

Table 1.--Chronology of dwarf mistletoe sanitations at Grand Canyon National Park

Years	Sanitation	Area treated
1949-52	Initial	Original control area
1954-55	Second	Original control area
1956-57	Initial	Extension area A
1961-62	Third	Original control area
	Second	Extension area A
1966-69	Fourth	Original control area south of highway in sections 17 and 20, roadside west of Section 4
	Third	Extension area A south of highway in Section 21 and western portions of Section 4
	Initial	Extension area B
1969-70	Fourth	Original control area north of highway in Sections 17 and 20
	Third	Extension area A in Sections 14, 15, 16, and 21

most of the area has been resanitized after about 5, 10, and 20 years.

A total of 6,932 trees (6.3 per acre) was treated in the initial sanitation and 4,220 (3.8 per acre) in the second (table 2). Only trees over 6 feet high are included because records for the smaller trees are incomplete. Fifty-three percent of the trees were pruned initially and 70 percent in the second sanitation. The proportion of trees pruned was highest in mature trees — 63 percent initially and 84 percent in the second sanitation.

Data are not available on the number of trees treated in the third and fourth sanitations of the original control area because the totals were combined with those from extension area A.

Extension Area A

Extension area A (see fig. 2) was initially sanitized in 1956-57; a second sanitation was made in 1961-62, and a third in 1966-70. Thus this area was resanitized after about 5 and 13 years. Data on the number of trees treated in area A are available only for the initial sanitation because data for 1961-62 and 1968-70 operations were combined with those for the original control area.

A total of 9,648 trees of all size classes was treated during the initial operation on extension area A. Of these, 33 percent (3.8 per acre) were pruned and the rest (7.7 per acre) killed.

Extension Area B

Extension area B was initially sanitized in 1966-69 (see fig. 2). There have been no further sanitations to date, but a second treatment is scheduled for 1973. Data are not available on the number of trees treated in extension area B because the totals were combined with those from other areas.

PERMANENT STUDY PLOTS

Description

Ten permanent study plots[3] totaling 31.17 acres were established in or near the original control area to obtain information on the success of the control operation (see fig. 2). Five plots were within the treated area and were subjected to the same control measures as in the surrounding stands; the other five plots were outside the control area and were left untreated. The treated plots were first sanitized in 1949-52, with subsequent sanitations in 1954-55, 1961-62, and 1966-70. As will be discussed later, treated Plot 2 has not yet had its scheduled third sanitation. All plots, except Plot 6, were established in 1950 (Hawksworth 1951). Plot 6 was set up in 1952. All trees on the plots were examined in 1955, 1961, 1966, and 1970.

Individual tree data were obtained on these plots by tagging trees over 4 inches in d.b.h. in 1950. At the time of the 1961 examination, all trees over 3.5 inches d.b.h. were tagged. Details on the numbers of trees and basal areas on these plots are given in tables 3 and 4.

The ten plots were divided into six groups as follows:

Plot 1 Series. — Two 10-acre plots, one treated and one untreated. This series was established to determine the effectiveness of control measures in heavily infected overmature stands in the eastern portions of the area.

[3] *Stands on the study area consisted of (1) reproduction — young trees up to 3.5 inches d.b.h.; (2) poles — young trees 3.6 to 11.5 inches d.b.h.; (3) blackjacks — young trees 11.6 inches d.b.h. and larger, with black bark and pointed top; (4) mature trees, 11.6 inches d.b.h. and larger, but usually less than 24.0 inches, with yellow bark and tops beginning to flatten; (5) overmature trees, usually over 24 inches d.b.h., with yellow bark and flat top.*

Table 2.--Number of trees, by size class (over 6 feet high and 4½ to more than 30 inches diameter at breast height), treated in the initial and second sanitations on the original control area (1,100 acres)

Size class	Initial Sanitation		Second Sanitation	
	Pruned	Killed	Pruned	Killed
	Number			
Mature (over 30 inches d.b.h.)	751	440	1,059	204
Intermediate (trees 4½ to 30 inches d.b.h.)	2,016	2,115	950	313
Saplings (trees 6 feet high to 4½ inches d.b.h.)	921	689	931	763

Table 3.--Stand composition and dwarf mistletoe infection by diameter class on treated and untreated plots
Grand Canyon National Park, 1950-70

	<6 inches				6-11 inches				12-23 inches				>23 inches				Total			
	Plot 1	Plot 2[1]	Plot 3[2]	Plot 4	Plot 1	Plot 2[1]	Plot 3[2]	Plot 4	Plot 1	Plot 2[1]	Plot 3[2]	Plot 4	Plot 1	Plot 2[1]	Plot 3[2]	Plot 4	Plot 1	Plot 2[1]	Plot 3[2]	Plot 4
	No. of trees																			
TREATED PLOTS--																				
Original stand, 1950:																				
Dead	1	4	2	6	6	2	4	1	12	1	1	1	3	0	0	0	22	7	7	8
Infected	28	57	5	184	35	77	5	11	71	35	14	0	27	2	0	0	161	171	24	195
Uninfected	22	39	4	70	13	49	1	0	10	19	11	0	1	2	2	0	46	109	18	70
Intentionally killed	11	29	2	100	14	31	3	6	54	8	3	0	11	0	0	0	90	68	8	106
Left	39	67	7	154	34	95	3	5	27	46	22	0	17	4	2	0	117	212	34	159
1951-70:																				
Ingrowth	9	34	0	0	3	1	0	0	0	0	0	0	0	0	0	0	12	35	0	0
Intentionally killed	4	22	1	94	11	22	0	5	11	11	0	0	4	0	0	0	30	55	1	99
Died	2	3	0	2	0	0	0	0	0	1	1	0	1	1	0	0	3	5	1	2
1970 stand:																				
Infected	0	10	0	2	3	32	1	1	2	20	2	0	0	1	0	0	5	63	3	3
Uninfected	5	23	4	45	42	70	4	10	29	29	19	0	15	2	2	0	91	124	29	55
Total	5	33	4	47	45	102	5	11	31	49	21	0	15	3	2	0	96	187	32	58
UNTREATED PLOTS--																				
Original stand, 1950:																				
Dead	1	0		0	9	8		0	15	2		0	2	0		0	27	10		0
Infected	32	27		44	56	50		34	84	55		6	51	1		0	223	133		84
Uninfected	29	35		10	23	18		9	11	29		3	4	3		0	67	85		22
Kill[3]	9	6		32	19	20		13	32	24		1	26	0		0	86	50		46
Ingrowth, 1951-70	15	1		0	16	0		0	0	0		0	0	0		0	31	1		0
Died, 1951-70	11	9		50	18	11		22	29	13		2	18	0		0	76	33		54
1970 stand:																				
Infected	15	22		5	59	53		21	80	56		7	39	2		0	193	133		33
Uninfected	13	17		1	28	11		4	7	23		1	4	2		0	52	53		6
Total	28	39		6	87	64		25	87	79		8	43	4		0	245	186		39
Kill[3]	12	11		5	36	36		20	48	30		8	25	0		0	121	77		33

[1] Plot 2 untreated includes combined data from both plots.
[2] No untreated are in plot 3.
[3] Trees that would have been killed if stand had been sanitized.

Table 4.--Basal area per acre by diameter class of trees on treated and untreated plots
Grand Canyon National Park, 1950-70

	<6 inches		6-11 inches		12-23 inches		>23 inches		Total	
	Plot 1	Plot 2	Plot 1	Plot 2	Plot 1	Plot 2	Plot 1	Plot 2	Plot 1	Plot 2
	Square feet									
TREATED PLOTS--										
Original stand, 1950:										
Dead	([1])	0.1	0.3	0.4	1.9	0.6	1.1	0.0	3.3	1.1
Infected	0.2	2.6	1.4	11.2	13.2	20.1	11.2	3.1	26.0	37.0
Uninfected	0.2	1.9	0.5	7.3	1.9	10.9	0.4	2.8	3.0	22.9
Intentionally killed	0.1	1.3	0.6	4.1	9.8	3.6	4.5	0.0	15.0	9.0
Left	0.3	3.1	1.4	14.5	5.2	27.4	7.0	5.9	13.9	50.9
1951-70:										
Ingrowth	0.1	1.4	0.1	0.2	0.0	0.0	0.0	0.0	0.2	1.6
Intentionally killed	0.1	0.6	0.4	3.2	1.7	5.3	1.5	0.0	3.7	9.1
Died	([1])	0.1	0.0	0.0	0.0	0.5	0.4	1.4	0.4	2.0
1970 stand:										
Infected	0.0	0.5	0.2	4.9	0.2	12.3	0.0	1.2	0.4	18.9
Uninfected	0.1	1.2	1.7	10.7	4.9	17.7	6.5	2.9	13.2	32.5
Total	0.1	1.7	1.9	15.6	5.1	30.0	6.5	4.1	13.6	51.4
UNTREATED PLOTS--										
Original stand, 1950:										
Dead	([1])	0.0	0.4	1.4	1.9	1.4	0.8	0.0	3.1	2.8
Infected	0.3	1.1	2.7	10.3	14.5	33.8	23.0	1.8	40.5	47.0
Uninfected	0.3	1.0	0.9	2.9	2.4	19.1	2.1	5.3	5.7	28.3
Kill[2]	0.1	0.2	1.0	4.1	5.4	13.9	11.7	0.0	18.2	18.2
Ingrowth, 1951-70	0.1	([1])	0.5	0.0	0.0	0.0	0.0	0.0	0.6	([1])
Died, 1951-70	0.1	0.4	0.9	2.7	4.6	7.9	8.2	0.0	13.8	11.0
1970 stand:										
Infected	0.2	1.0	2.8	10.1	13.0	36.1	17.5	3.6	33.5	50.8
Uninfected	0.1	0.6	1.2	1.9	1.3	17.3	2.1	3.8	4.7	23.6
Total	0.3	1.6	4.0	12.0	14.3	53.4	19.6	7.4	38.2	74.4
Kill[2]	0.1	0.5	1.8	6.9	7.6	18.7	11.3	0.0	20.8	26.1

[1] Basal area less than 0.1 square foot.
[2] Basal area that would have been killed if stand had been sanitized.

Plot 2 Series. — Three plots — a 2.62-acre treated plot, and two untreated plots of 1.25 (2A) and 1.05 acres (2B). This series was established to determine the effectiveness of control measures in heavily infected blackjack stands in the western portions of the area.

Plot 3. — One plot of 0.51 acre. This plot was established to study effectiveness of treatment in a single infestation center in a blackjack stand.

Plot 4 Series. — Two plots — a treated plot of 0.41 acre and an untreated plot of 0.52 acre on the Kaibab National Forest just south of the National Park boundary. This series was established to determine the effectiveness of control measures in heavily infected reproduction and pole stands.

Plot 5. — One plot of 0.1 acre. This plot was established to determine the effectiveness of control measures in severely infected dense reproduction.

Plot 6. — One plot of 4.80 acres. This plot was established to determine the rate of invasion of dwarf mistletoe through a mature untreated stand.

Study Plot Results

Plot 1 Series

The stand and disease characteristics in 1950 and 1970 on the treated and untreated plots in the heavily infected mature ponderosa pine forests in the eastern portion of the control area (figs. 3-5) are summarized in table 5. The plots were comparable before treatment in 1950: 78 percent of the trees infected with an average plot rating of 2.8 on the 6-class scale[4] on the treated plot, and 77 percent of the trees infected with an average plot rating of 2.7 on the untreated plot. In 1950, the number of dead standing trees killed by mistletoe was also similar on both plots: 22 on the treated plot, and 27 on the untreated plot.

In the original sanitation, 9.0 trees per acre were killed, and 7.1 pruned on the treated plot. Subsequently, 3.0 more trees per acre were killed. By 1970, 9.6 trees per acre remained, but 95 percent of these were mistletoe-free. In contrast, 7.6 trees per acre were killed by dwarf mistletoe on the check plot, and the proportion of trees infected increased from 77 to 79 percent. If the current mortality rate continues, the untreated stand will have lost more trees by about 1985 than were killed or died on the treated area, and the untreated area will still be heavily infected with dwarf mistletoe.

Perhaps the most meaningful comparison is the average plot mistletoe rating in 1950 and 1970. This figure, based on all live trees in the plot, gives a useful overall comparison of the amount of mistletoe present. The extent of infection on the untreated plot in 1970 (mistletoe rating 3.5) was about 35 times that on the treated plot (mistletoe rating 0.1).

To evaluate the ponderosa pine reproduction, 100 0.004-acre temporary microplots, spaced on a 1-chain grid, were established in both Plots 1 treated and untreated in 1972. The age of each tree under 4 inches d.b.h. was estimated to be more than, or less than, 20 years old by counting the number of branch or stem whorls. Reproduction in the treated plot was found to be free of infection (table 6) and so abundant that a well-stocked, esthetically pleasing ponderosa pine stand can be expected. On the untreated area, however, pine reproduction is already infected (8 percent of the trees under 20 years and 13 percent of those over 20 years). This stand will probably never reach maturity, and will have minimal recreational potential.

Reproduction over 20 years old is somewhat more abundant on the untreated plot (table 6) because most of the visibly infected trees were removed on the treated plot. The number of trees less than 20 years old, however, is over five times greater on the treated area. Also, reproduction on the treated area is more uniformly distributed. (Twice as many microplots had trees under 20 years old on the treated area.) Some possible explanations for this condition are: (1) The more abundant production of viable seed by mistletoe-free and lightly infected trees, (2) creation of better seedbed conditions due to exposure of mineral soil by control activities, and (3) the wider spacing between older trees allowing for better survival of young trees.

The original observation that Gambel oak was replacing the ponderosa pine type in some heavily infested areas of the park (Gill 1949) has not yet been documented. Data taken in 1972 on Plots 1 treated and untreated showed no significant difference in the number of oak sprouts or seedlings. A time period much longer than the 20 years covered by this examination will probably be necessary to establish the relationship between dwarf mistletoe control activities and oak populations.

[4] *For this 6-class rating system, the crown of each tree is divided horizontally into thirds (Hawksworth 1961). Each third is then given a rating of zero (no mistletoe), 1 (light mistletoe), or 2 (heavy mistletoe). The three ratings are then totaled to give a tree rating which may range from zero (no mistletoe) to 6 (each third of the crown heavily infected). The ratings of all live trees are then averaged to obtain a plot rating.*

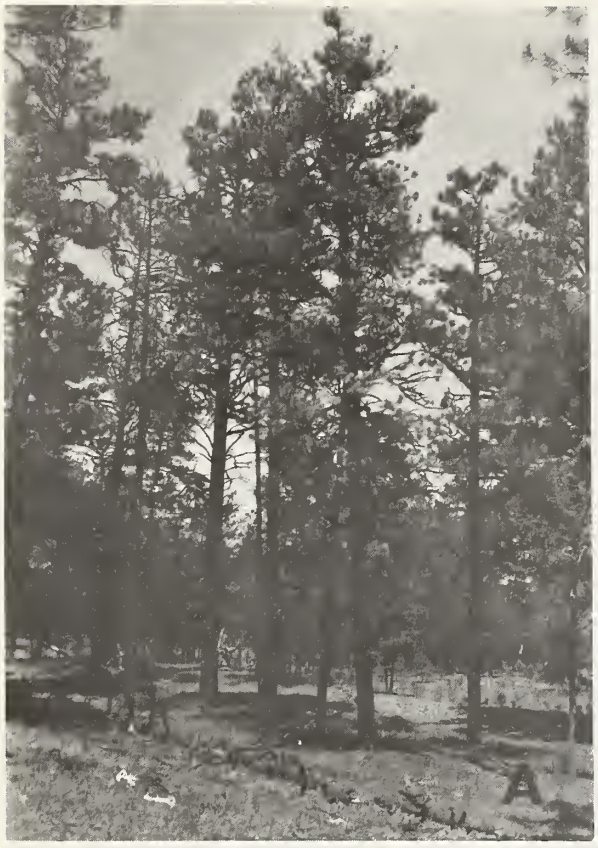
Figure 3.—
Plot 1 Treated, from the southeast corner:

A, 1949, before treatment;

B, fall of 1950, about a year after initial sanitation;

C, D, August 1971.

Note that reproduction has obscured the view in C; D was taken from about 15 feet above the original camera point.



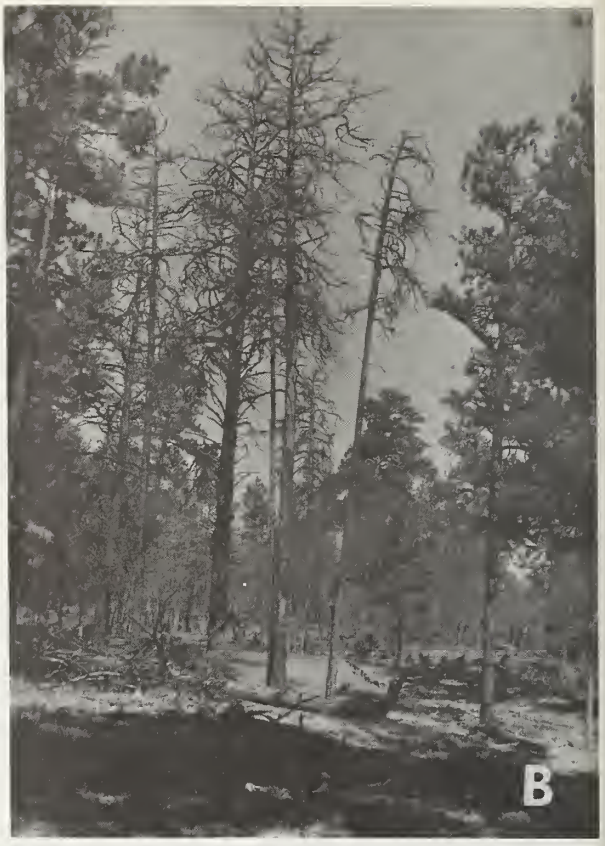


Figure 4.—
Plot 1 Untreated, near the southeast corner:

A, June 1950;

B, May 1955;

C, May 1971.

Figure 5.—Deterioration of the mature forest, due to the effects of dwarf mistletoe, represented by two areas in Plot 1 Untreated:

A, June 1950;
B, May 1971;
C, June 1950;
D, May 1971.

Table 5.--Comparison (per-acre basis) of treated and untreated stands, Plots 1 and 2, Grand Canyon National Park, 1950-70

Plot description	Natural mortality of trees, 1950-70	Trees		Basal area		Average d.b.h. live trees	Dwarf mistletoe rating
		Total	Healthy	Total	Healthy		
	No.	No.	Percent	Sq. ft.	Percent	Inches	
PLOT 1 (MATURE)							
Treated	0.5						
1950		20.7	22	29.0	10	13.5	2.8
1970		9.6	95	13.6	97	14.2	0.1
Difference		-11.1	+73	-15.4	+87	+ 0.7	-2.7
Untreated	7.6						
1950		29.0	23	46.1	12	14.5	2.7
1970		24.5	21	38.2	12	13.9	3.5
Difference		- 4.5	- 2	- 7.9	0	- 0.6	+0.8
PLOT 2 (BLACKJACK)							
Treated	1.9						
1950		106.7	39	22.8	38	9.2	1.7
1970		71.2	66	19.6	63	10.3	0.7
Difference		-35.5	+27	- 3.2	+25	+ 1.1	-1.1
Untreated	14.3						
1950		94.8	39	32.8	38	10.4	1.8
1970		80.9	28	32.3	32	11.5	2.9
Difference		-13.9	-11	- 0.5	- 6	+ 1.1	+1.1

Table 6.--Ponderosa pine reproduction (trees per acre under 4 inches d.b.h.) on Plot 1 series (based on 100 0.004-acre microplots on each plot)

	Total trees	Microplots with trees		Dwarf mistletoe-infected trees
		Mean ± SE[1/]		
	No.	- - Percent - -		
Trees less than 20 years old:				
Treated plot	510	46 ±	10	0
Untreated plot	95	20 ±	8	8
Trees more than 20 years old:				
Treated plot	235	23 ±	8	0
Untreated plot	415	37 ±	10	13

[1/] Standard error.

Plot 2 Series

The stand and disease characteristics on the treated and untreated plots in the heavily infected blackjack stands in the western portions of the control area (figs. 6-7) are summarized in table 5. The plots were comparable before treatment in 1950: 61 percent of the trees were infected on both plots; the average plot mistletoe rating on the treated plot was 1.7 while that on the untreated plots was 1.8.

Since control started, 2 trees per acre on the treated plot have died of natural causes, and 21 trees per acre have been killed by treatment; 24 (34 percent) of the remaining trees were infected in 1970. On the untreated plots, 14 trees per acre have died, and 72 percent of the trees were infected in 1970. The average dwarf mistletoe rating was reduced from 1.7 in 1950 to 0.7 in 1970 by the control operations, but on the untreated plots the rating during this 20-year period increased from 1.8 to 2.9.

Control appears to have been less effective for this heavily infected blackjack stand than it was for the mature stand (Plot 1 Series). Additional considerations are necessary to understand this situation.

At the time of the 1970 examination, Plot 2 Treated had not yet received its scheduled fourth sanitation, and thus had not been treated since 1961. Fifty-two of the 63 trees now infected with dwarf mistletoe were infected in 1966 and should have been treated at that time. Had this been done, 12 trees would have been killed and the rest pruned. The number of trees showing new infections in 1970 would

Figure 6.—Deterioration of the young forest, due to the effects of dwarf mistletoe, represented by two areas in Plot 2A Untreated:

A, June 1950;
B, May 1971;
C, June 1950;
D, May 1971.

Figure 7.—Deterioration of the young forest, due to the effects of dwarf mistletoe, represented by two areas in Plot 2B Untreated:

A, June 1950;
B, May 1971 (note increase in height growth of Gambel oak);
C, June 1950;
D, May 1971.

undoubtedly have been reduced much below the 11 that were found, and the number of previously infected trees that are still infected would have been correspondingly lower.

What has happened on Plot 2 Treated is a good indication of what will happen when control efforts are stopped. A popular picnic area was installed in the northeast corner of this treated plot after its establishment. Without further treatment to control dwarf mistletoe, tree mortality in this area will accelerate. The stand adjacent to the picnic ground can be expected to become thin, and the foliage on the living trees will turn yellow. Its usefulness will, therefore, be greatly impaired, and it may eventually have to be abandoned because of the danger of dead trees falling on picnickers or their vehicles.

Plot 3

This single infestation center, in a 100-year-old blackjack stand, covered about 1/4 acre and involved 31 trees, 7 of which had been killed by dwarf mistletoe (see table 3). An additional 18 uninfected trees surrounding the center were included in the plot. In sanitizing this plot, 7 trees were killed and 16 pruned. One tree died in the 1950-70 period from causes other than mistletoe. Only three of the original trees in the center were infected in 1970, and there have been no newly infected trees. In 1950, 57 percent of the trees on the plot were infected, and the average plot mistletoe rating was 1.5. In 1970, 9 percent of the trees were infected and the average mistletoe rating was only 0.1. Control has clearly reduced the dwarf mistletoe population to an insignificant level.

Plot 4 Series

At the time of establishment, the treated plot contained groups of saplings, small poles, and very heavy reproduction in the south half (see table 3). The untreated stand differed in that there was much less reproduction, and some of the dominant trees were larger (see table 3). Dwarf mistletoe infection was comparable on the plots. The treated plot had 73 percent of the trees infected, and an average plot rating of 2.8; the untreated plot had 79 percent of the trees infected, and an average plot rating of 2.4.

No detailed comparison can be made between the plots because eight of the largest trees on the untreated plot on the Kaibab National Forest were cut in 1968. On the treated area, 258 trees per acre were killed during the original treatment in 1950, and an additional 241 trees per acre were killed in re-treatments, but only five other trees have died. Of the 141 trees per acre in 1970, 5 percent were infected, and the average plot mistletoe rating had been reduced from 2.8 in 1950 to 0.05. When the untreated plot was last examined in 1972, 104 trees per acre had died, and 88 percent of the remaining 96 trees per acre were dwarf mistletoe infected. The average plot rating increased from 2.4 in 1950 to 4.0 in 1972.

Even these marked differences do not portray the whole story, because the treated plot is now covered with a thrifty stand of young, mostly uninfected trees, whereas the untreated plot has virtually nothing but small dead and dying trees.

Plot 5

Although the overstory trees which were responsible for the infection were killed during treatment or died due to dwarf mistletoe, the reproduction was infected prior to treatment. In 1950 there were 3,250 trees per acre under 12 feet high on this plot. Forty-nine percent of these were infected, and most infected trees (1,200 per acre) were cut in 1950. Subsequent operations removed some additional trees. In 1972, only 2 percent of the remaining 1,370 trees per acre were infected. Thus the remaining stand of young trees is thrifty, and virtually free from dwarf mistletoe.

Plot 6

This plot is along the edge of the range of dwarf mistletoe about a mile from the canyon rim (see fig. 2). In 1952, 17 percent of the 251 trees on the plot were infected, and the average plot mistletoe rating was 0.4. In 1972, 34 percent of the trees were infected and the average plot rating had risen to 1.1. Detailed analyses on the rate of spread of dwarf mistletoe on this plot will be published elsewhere.

Analysis of Untreated Plots

Analysis of the data from the untreated plots (1, 2, 4, and 6) provides an insight into behavior of dwarf mistletoe on the South Rim.

A plot of the 20-year change in average basal area per tree for trees uninfected, and the six mistletoe infection classes, in 1950 (fig. 8)

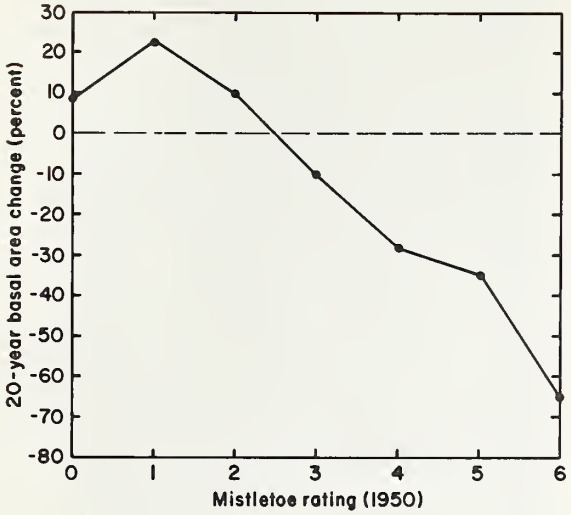


Figure 8.—
Comparison of the 20-year basal area growth of 864 trees of various dwarf mistletoe infection classes on the untreated plots.

shows the effects of dwarf mistletoe on growth rate and mortality combined. The data are similar to the 11-year results on these plots published by Lightle (1966). The figures were obtained by dividing the total living basal area in 1950 and 1970 by the number of trees in each infection class in 1950. Uninfected trees and those in infection classes 1 and 2 increased in basal area by 10 to 20 percent during the period. Average basal area per tree fell below the 1950 level between infection classes 2 and 3, and decreased markedly in higher infection classes, reaching 65 percent less in class 6. The larger basal area change in infection class 1 over that of uninfected trees is due to their larger size, and not to stimulation by dwarf mistletoe. The trees in infection class 1 averaged about 1 inch in diameter larger than the uninfected trees in 1950.

Mortality during the 20-year period was directly related to intensity of dwarf mistletoe:

Dwarf mistletoe rating (1950)	Tree basis (Number)	Mortality between 1950 and 1970 (Percent)
0	361	4
1	88	3
2	83	12
3	59	27
4	46	37
5	62	42
6	60	63

Mortality rate in heavily infected (class 6) trees was more than 15 times that of healthy trees. The life expectancy of class 6 trees averages about 30 years, but will vary according to the sizes and ages of the trees.

Dwarf mistletoe intensified rapidly in the mature trees on untreated Plots 1 and 6. Mistletoe ratings of trees in classes 1 through 4 in 1950 advanced to the next higher rating in about 9 years. This is somewhat faster than other areas in the southwest that have been studied.

CONCLUSIONS

The conclusions drawn here apply to the original control area first sanitized in 1949-52, and to extension area A first treated in 1956-57. The control on extension area B has been too recent (1966-69) to evaluate its effectiveness.

Dwarf mistletoe populations in the treated plots were markedly reduced. For example, on the Plot 1 Series, the extent of dwarf mistletoe infestation (based on average plot mistletoe ratings) after 20 years is over 35 times as high on the untreated as on the treated plot.

In detailed examinations of the control area in 1965 by several Park Service personnel and the senior author, only 287 infected trees were found in an area of about 750 acres during 25 man-hours of intensive searching. These infected trees were generally in small groups, and lightly infected, usually with only one or two dwarf mistletoe plants per tree.

The results from the permanent plots plus examinations of the control area outside the plots clearly indicate that the original goal of the project—to reduce the level of dwarf mistletoe and protect the ponderosa pine forest—has been achieved. This has generally been accomplished without undue alteration of, or disturbance to, the ponderosa pine stands within the treated area. These stands are now

thrifty, relatively free of dwarf mistletoe, and contain ample reproduction to insure the perpetuation of ponderosa pine along the scenic East Rim Drive.

SUGGESTIONS FOR DWARF MISTLETOE CONTROL IN RECREATIONAL FORESTS

The 20-year results of the Grand Canyon control project have yielded much information that may be useful in future operations in recreational forests.

1. In general, pruning should be limited to lightly infected trees (classes 1 or 2). Removal of more than 50 percent of the live crown is not recommended. The number and extent of sanitations necessary is directly related to the proportion of trees pruned initially. In the initial sanitation of the original control area, more than half of the trees were pruned in an attempt to save as many trees as possible. This necessitated many subsequent recleanings, because most trees had to be repruned, some of them two, three, or even four times. Also, pruned trees frequently developed so much reinfection that they had to be killed later. We suggest that the more recent operations, in which about 20 to 30 percent of the trees were pruned, were more successful because pruning was limited to lightly infected trees. Successful elimination of dwarf mistletoe by pruning is strongly correlated with amount of infection in the tree at the time of the initial operation because many pruned trees have to be killed later:

Original dwarf mistletoe rating	Proportion of pruned trees alive 20 years later (Percent)
1	70
2	50
3	40
4	10

2. Pruning should be confined, as far as possible, to the more isolated trees. Pruning even lightly infected residual trees in once heavily infected groups of pole-sized trees was generally unsuccessful. In such situations nearly all the pruned trees had to be repruned, and half of them were so heavily infected that they had to be killed.

3. In pruning, the infected branch should be cut off at the bole. Although it may at first appear easier to remove infected secondary or tertiary branches, the high incidence of latent dwarf mistletoe in the remaining branches makes this practice questionable. In most cases the branch has to be removed in subsequent prunings.

4. If large portions of the crown are removed by pruning, isolated living branches should not be left. Even though dwarf mistletoe may not be apparent in such branches, they almost invariably harbor incipient infections. Where it is possible to do so without removing too many branches, pruning for two or three whorls above the highest visible mistletoe should eliminate many latent infections and thus save a considerable amount of time in subsequent sanitations.

5. Prunability of branches is related to branch diameter. The rule applied in the early work—that trees with infections within 18 inches of the main stem (later reduced to 12 inches) were not considered to be prunable—has been found to be too restrictive. Extent of the endophytic (or root) system of ponderosa pine dwarf mistletoe is now known to be as follows (Hawksworth and Andrews 1965):

Branch diameter at bole	Minimum safe distance from bole to closest shoots (Inches)
Under 1 inch	6
1 to 2 inches	8
2 to 3 inches	10
3 to 4 inches	12

This guide need not be followed if the bole diameter at the infected branch is 8 inches or more (see suggestion number 6).

6. Not all trees with bole infections need be killed. The original guides suggested that trees larger than 12 inches in diameter did not need to be killed merely because they had infections in the main stem. This was based on the observation that infections on the boles of large trees are usually not vigorous, and therefore are negligible sources of infection to surrounding trees. Research is now underway to determine more precisely the relationship between diameter and vigor of bole infections. We tentatively suggest, however, that trees with infections on the bole, where the diameter at the point of infection is over 8 inches, offer very little threat to surrounding trees and need not be sacrificed.

7. Pruning heavily infected trees will prolong their life. We made a small study to determine the extent to which heavily infected trees would recover if the infected branches were pruned out. These heavily infected trees were usually of infection class 4 or even 5, and would have been killed in accordance with the marking rules for the rest of the control area. A series of 45 trees were pruned in 1950. Many of these were so severely infected that the tops of the crowns were thin and off-color due to the effects of the parasite. The results (figs. 9-10) show that such trees can recover, even

Figure 9.—

Increased vigor of a 17-inch d.b.h. blackjack tree 11 years after removal of dwarf mistletoe-infected branches:

A, June 1950, before pruning;

B, June 1952, after pruning;

C, September 1961.

Note the difference in crown density and needle length between A and C.

Figure 10.—
Increased vigor of a 32-inch d.b.h. mature ponderosa pine 11 years after removal of dwarf mistletoe-infected branches:

A, May 1950, before pruning;

B, June 1952, after pruning;

C, September 1961.

Note the difference in crown density and needle length between A and C.

though dwarf mistletoe is not necessarily eliminated from them. By removing the lower infected branches which are seriously reducing the vitality of the tree, the life span of the tree can be prolonged considerably. While such drastic pruning is not recommended as a routine control measure, it can be used to lengthen the life of particularly valuable or needed trees.

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1973. Control of dwarf mistletoe in a heavily used ponderosa pine recreation forest: Grand Canyon, Arizona. USDA For. Serv. Res. Pap. RM-106, 22 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo. 80521.

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Oxford: 443.3:412. **Keywords:** Dwarf mistletoe control, recreational forests, silvicultural control, *Arceuthobium vaginatum* subsp. *cryptopodum, Pinus ponderosa.*

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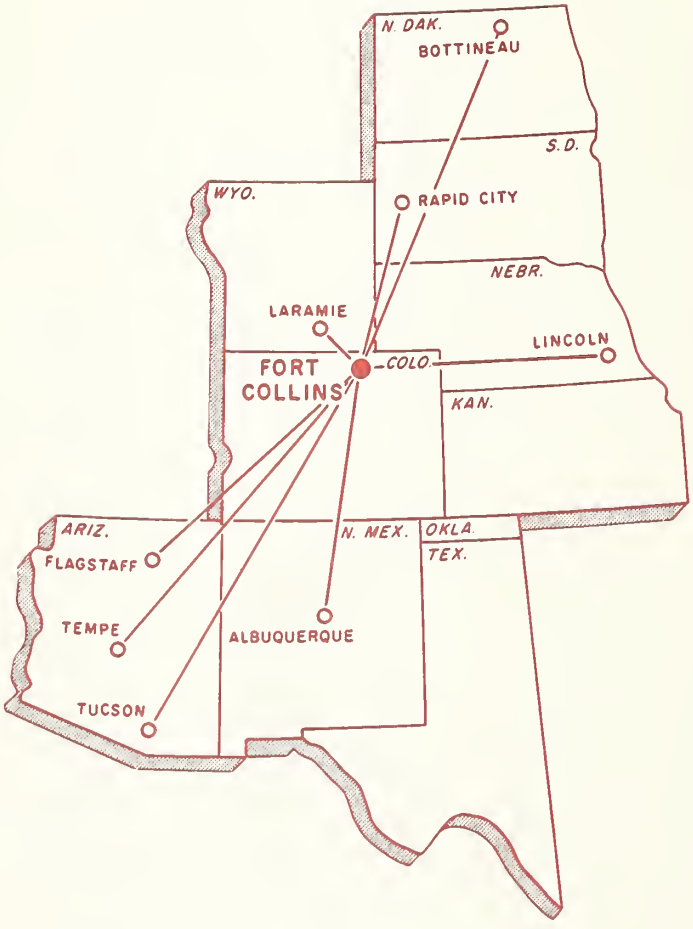
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